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Five Grand Challenges in Pedestrian and Evacuation Dynamics

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The purpose of this paper is to define five grand challenges which impede quantum progress in the field of pedestrian and evacuation dynamics. The emerging field of pedestrian and evacuation dynamics (PED) has widely distributed research efforts, has limited resources relative to the magnitude of the problem, and lacks a consensus research agenda. By marshalling the limited resources towards collectively or systematically addressing significant issues, the field can mature more rapidly. Each of the challenges described herein must be addressable within the next ten years, given appropriate resources and, once solved, the solution must enable significant progress in the field. While this list is not comprehensive or complete, the purpose is to engender spirited discussion about necessary research priorities, along with what steps, metrics, and resources will be required for making progress.

Grand Challenge #1: Develop and validate a comprehensive theory that predicts human behavior during pedestrian or evacuation movement.

Ball bearing and other physics-based models are inadequate to predict the full range of possibilities for pedestrian and evacuation scenarios. The phenomena are people making predictable decisions when confronted with predictable information and conditions, rather than robots or inanimate objects responding to laws of nature. The first step will require theoretical models, several variants of which already exist. The second step will be to develop methods (beyond observational) which can validate the components of the theoretical models, which may be more difficult for evacuation than pedestrian scenarios. The final step is to integrate the theoretical models into the pedestrian and evacuation computational models.

Grand Challenge #2: Create a comprehensive database of actual emergency data.

The field of pedestrian and evacuation dynamics has developed largely on the foundation of a small number of (30+ year old) data sets. The data is routinely extrapolated far beyond the scope of the original data. Virtually no information exists which examines the applicability of the existing data for real emergency scenarios. A comprehensive database which catalogues the progress and outcomes for real emergency incidents (the crucible in which theory and drills are tested) is necessary condition for acceptance and validation of all knowledge in the field. Establishment of the database will require methods to document initial conditions, incident environmental conditions, and occupant information and responses, both during the incident and post-incident. Even if the researchers knew when and where an event would occur, the infrastructure to collect, analyze, and archive the data has not yet been developed.

Grand Challenge #3: Embrace variance.

The vast majority of current generation models are deterministic. Pedestrian movement and building evacuations are highly stochastic processes. Evacuate the same building with the same people starting in the same places on consecutive days and the answers could vary significantly. The PED community must move away from terms such as average and evacuation time, and adopt tools and techniques which manage distributions of inputs and outputs. Probabilities should be attached to the distributions and a discussion of acceptable risk should take place in every nation and community.

Grand Challenge #4: Integrate results of evacuation models with fire models to enable accurate and reliable performance-¬based design

The calculation of Available Safe Egress Time (ASET) is light-years ahead of any reliable and validated prediction of Required Safe Egress Time (RSET). The interaction of the occupants with the constraints imposed by the emergency (e.g., people evacuating through smoke) has implications for a host of disciplinary contributions (toxicology, psychology, sociology, architecture, engineering, mathematics, to name a few). Scenarios equivalent to the SFPE fire safety design scenarios should be developed for building evacuation. In addition, both of these concepts are distributions (as discussed in Grand Challenge #3), and methods for combining the outcome distributions in a meaningful way that can be understood by the design and regulatory communities for safe and cost-effective building design must be developed prior to realization of the full potential for performance based design.

Grand Challenge #5: Embrace technology.

Given the paucity of data on simple concepts (such as stairs), it should not surprise anyone that virtually no data exist for use of technology to improve building evacuation effectiveness. Technologies exist and are being developed based on integration of building sensor information, communication technologies, active signage, and movement technologies, such as elevators, escalators, and alterative escape devices. For these technologies, there are virtually no experimental data, incident data, theoretical models, or computational algorithms to encourage adoption of more effective strategies. The PED community must lead the way in enabling the enhancements by proactively seeking and developing technologies through data and models.

Conclusions

The emerging discipline of PED has many challenges and limited resources. For the field to mature, the community must identify and adopt theoretical and computational approaches that have sound basis in experimental and emergency incident science. Designers and regulators must have standards of practice and computational tools which enable evaluation of a wide variety of scenarios and solutions. When these standards and tools are widely available and understood, occupants will be able to use and evacuate structures more reliably, efficiently, and with less total cost to society.

Session: Data Collection (Evacuation)

Data Collection (Evacuation)
Chaired by: Daniel Nilsson

Emergency Door Capacity: Influence of Population Composition and Stress Level
Winnie Daamen and Serge Hoogendoorn

Overall and Local Movement Speeds During Fire Drill Evacuations in Buildings Up to 31 Stories
Richard Peacock, Bryan Hoskins, and Erica Kuligowski

Predicting a Probability of Evacuation Congestion Occurrence relating to Elapsed Time and Vertical Section in a High-rise Building
Jun-ho Choi, Hyun-seung Hwang, and Won-hwa Hong

Employing Human Egress Data
Steven Gwynne

Emergency Door Capacity: Influence of Population Composition and Stress Level

W. Daamen and S.P. Hoogendoorn, Delft University of Technology

Since 1992, the Dutch national building code ("Building decree") sets requirements to the width of emergency doors. Since 2003, these requirements depend on the number of persons that rely on an emergency door. According to the Building decree a door width of 1 meter is sufficient to let 135 persons pass during the period available for safe escape (1 minute). This value corresponds to research of Peschl (1971), being 2.25 P/s/m.

The threshold of 135 persons per meter width during a safe escape time of one minute has been discussed for years between the Ministry for Housing, Regional Development and the Environment and the fire brigades that are used to allow a maximum of 90 persons per meter width during a safe escape time of one minute (similar to 1.5 P/s/m).

To get insights into the capacity of emergency doors in the current situation, the Delft University of Technology has performed new experimental research on emergency doors. The capacity of an emergency door depends on several aspects, among which the composition of the population using the door, the door width and the conditions under which the door is used. In this paper, the influence of the composition of the population and their stress level is discussed in detail. Earlier publications (Pauls, 2008) show the large influence of physical abilities on capacities and other traffic characteristics, and the question is whether differences in physical abilities not only change over the years, but also might be significantly different between individual persons.

In the experiments, the emergency door is represented by an opening: subjects pass a free passage of a certain width. In this opening, no doorstep is present, to reduce hindrance and prevent possibly dangerous situations for participants. In addition, the pedestrian flow is one directional, which means that no counter flows are present caused by fire fighters and people from emergency services. In reality, these people will rarely enter a building when the evacuation process is still going on.

The experiments performed by Peschl (1971) have been based on a student population. However, in practice, the population will not consist of persons being in good shape, but the persons will have diverse physical conditions. This condition both depends on their age and on their constitution. Here, we distinguish three categories: children (under 18 years of age), adults (between 18 and 65 years of age) and elderly (over 65 years of age). With these age categories, we are able to compose populations corresponding to a variety of situations. The disabled people are three persons in wheelchairs and three blindfolded persons.

In addition, the doorway width is varied with multiples of 55 cm between 50 cm (the minimal free passageway of an escape route in the Building decree for existing buildings) and 275 cm. In addition, openings of 85 cm wide (minimal free passageway of an escape route in the Building decree for new estates) and 100 cm (used as expression of capacity) have been applied. Furthermore, the conditions under which an emergency door is used may vary considerably. In the experiments, the stress level of the participants and the sight are varied. The stress level of the participants is raised by a slow-whoop signal and a combination of the slow-whoop signal and stroboscope light. The sight is reduced by blacking out, resulting in full lighting conditions (200 lux) and emergency lighting (1 lux). Finally, the influence of a fixed door open under an angle of 90 degrees present in the doorway has been tested.

Ideally, all combinations of experimental variables should be investigated. Since this is not feasible due to time restrictions, for each experiment one variable is changed, while for the other variables the default value is maintained. The stress levels are varied for all experiments. The default values are 85 cm for the door width, an average population, a normal light intensity and no open door present. For each experiment, different runs have been performed to get statistical reliability.

The experiments have been performed in a large hallway. To record the experiments, digital video cameras have been attached to the ceiling at a height of 10 meters. From the video images, individual trajectories have been extracted. In addition, capacities have been derived directly from the video images using a technique similar to photo finish photos (Daamen and Hoogendoorn, 2009). From the resulting cumulative curve at a cross-section immediately downstream of the doorway, capacities can be estimated. The slope of this cumulative curve is constant, indicating that the flow through the door is constant throughout each run.

Five out of six populations result in a capacity higher than the capacity threshold indicated in the Building decree. Only the population with 5% disabled persons results in a slightly lower capacity of 2.0 P/m/s. The population with mainly children has the highest capacity. This is not only caused by the enthusiasm of the children to be the first to pass the door, but also by the physical fact that children are smaller than adults, which makes it possible for more children to pass a door at the same time. The populations representing an elderly home, a meeting and a shopping centre do not differ much. Conversely, the capacity of the population 'station' varies considerably from the population 'meeting'. The first population consists only of adults, while the second population consists of 90% adults, completed with 5% children and 5% elderly. However, the difference between both capacities is somewhat more than 8%. Also the population 'shopping centre' and 'average' have a substantially different capacity (15%), while the first population has only 5% more children, 5% more adults and 10% less adults. These differences might be explained by the moment of the day the experiment has been performed.

The variation in capacity is highest for the school population, which can be attributed to the fact that children strongly react to each other: if the first person passes the door opening very fast, the others will follow very fast as well, whereas if the first person passes the door opening very slow, the others will also take it easy. However, the variation between the experiments with the stroboscope was very small, probably because this unusual external condition makes the children focus more on the aim of the experiments (less distraction).

With respect to the stress level, more stress appears to increase the capacity: the capacities are the lowest when there is no stress, followed by the slow-whoop signal and they are the highest for the slow-whoop signal together with a stroboscope light. The stress levels mainly have an effect for the first three runs of each stress level. Apparently, pedestrians do get used to the stress level and are less affected by it when they have become used to it. Some additional conclusions can be drawn from more detailed analyses: when there is no stress, more often only a single pedestrian passes the doorway at a time and the smallest time headways 'inside' the doorway occur for the highest stress level. This does mean that stress level has an effect on the microscopic pedestrian behavior.

The presented analyses make it possible to derive a theory on emergency behavior near evacuation doors in relation to population composition and stress level, which can be included in (simulation) models to more reliably assess buildings and other public areas on emergency situations.

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Overall and Local Movement Speeds During Fire Drill Evacuations in Buildings Up to 31 Stories

R. D. Peacock, B. Hoskins, and E. D. Kuligowski, National Institute of Standards and Technology

Occupant descent down stairwells during building evacuations is typically described by measureable engineering variables such as stairwell geometry, speed, density, and pre-evacuation delay. In turn, predictive models of building evacuation use these variables to predict the performance of egress systems for building design, emergency planning, or event reconstruction. As part of a program to better understand occupant behavior during building emergencies, the Building and Fire Research Laboratory at the National Institute of Standards and Technology (NIST) has been collecting stairwell movement data during fire drill evacuations of office buildings. These data collections are intended to provide a better understanding of this principal building egress feature and develop a technical foundation for future codes and standards requirements. To date, NIST has collected fire drill evacuation data in 8 office building occupancies ranging from six to 31 stories in height that have included a range of stairwell widths and occupant densities.

While average movement speeds in the current study are observed to be quite similar to the range of literature values, local movement speeds as occupants traverse down the stairwell are seen to vary widely within a given stairwell due to crowding or occupant mobility. These data should provide confirmation of the adequacy of existing literature values typically used for occupant movement speeds or provide updated values for future analyses.

Predicting the Probability of Evacuation Congestion Occurrence Relating to Elapsed Time and Vertical Section in a High-rise Building

Jun-ho Choi*, Hyun-seung Hwang and Won-hwa Hong, School of Architecture and Civil Engineering, Kyungpook National University

It is very important to predict human behavior in fire and to take measures for evacuation time however it is difficult to predict individual responses and dangerous to perform a field experiment. According to the Final Report on the Collapse of the World Trade Center Towers from the NIST, 2005, it took an average of 48 seconds for evacuees to descend to the floor below. It was more than twice the time it would ordinary take. The evacuees needed to be rescued more than once during their descent due to physical fatigue.

The evacuation behavior of evacuees that have descended staircases repeatedly causes physical fatigue or dizziness which obstructs evacuation traffic leading to evacuation congestion and delay. Evacuation congestion is amplified in high-rise buildings due to a decline in physical strength of evacuees caused by the inordinate length of evacuation lines and the confluence of new evacuees at each floor.

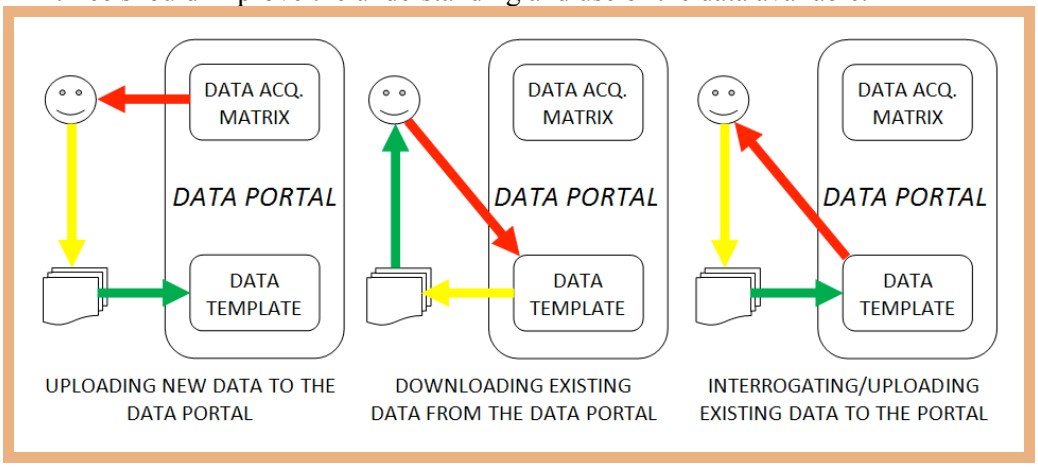
In this paper, a field evacuation experiment with 351 participants was performed. Through the statistical analysis of the evacuation behaviors recorded by CCTVs, the probability of calculating the evacuation congestion from each floor was estimated and occurrence patterns relating to time and vertical space were analyzed.

Employing Human Egress Data

Steven Gwynne, Hughes Associates, Inc.

Empirical data provides the bridge between reality and understanding. Data-sets enable engineers and scientists alike to form theoretical models that represent our understanding of the real world, and then apply these models to engineering applications. As such, empirical data-sets form the foundation of the engineering process. Unfortunately, there are a number of issues with the data currently available. Human egress data-sets are scarce. This scarcity is due to a number of factors: the relative immaturity of the field, the comparatively recent identification of the importance of human behavior in egress calculations, technical factors relating to data collection methods, matters of privacy and commercial sensitivity, and a range of other procedural and political factors. The data-sets currently available are relatively narrow in scope: they tend to focus on the physical component of egress performance, rather than the behavioral. The data-sets are derived from a range of sources and locations. This variety can add to the richness of the data-sets available; however, it includes data imported from adjacent fields (e.g., circulation movement) in order to fill the gaps in the data currently available. In addition, many of the egress data-sets collected, and frequently used, are several decades old. These problems lead to critical weaknesses in our understanding of real-world phenomena, develop theories and also in our attempts to model these phenomena. Data are often difficult to find, difficult to understand, and difficult to apply.

As part of a NIST-funded project guidance has been developed to inform the collection and representation of human egress data. This work provides a data acquisition matrix to inform the data collection process and a data template outlining the information required to adequately describe data collected. These two tools, along with several others, will then be provided in an online data portal. Once the data portal is fully implemented a central repository of data will be created that provides tools to facilitate the storage, representation and access to the data needed for researchers and engineers alike. As such, data should be more clearly represented, described in sufficient detail and more easily found. This can be used to inform the data collection and dissemination process (below left), the use of data made available through the portal (below center), and the interrogation of existing data using the template provided (below right). All three should improve the understanding and use of the data available.



As a prelude to the implementation of the data portal, this article describes how the representation of egress data can influence the engineering process – in both beneficial and harmful ways. Three example data-sets are presented and then employed:

1. A data-set with a limited representation of the quantitative data (e.g., compiled range and average of the data available), with limited background information and little or no qualitative information available.
2. A data-set with a more comprehensive representation of the quantitative data, accompanied by description of the qualitative conditions present (e.g., route usage).
3. A data-set including the raw data from the incident accompanied by a comprehensive description of the incident itself and the methods used to collect the data.

A discussion will be presented for each of these three data-sets. Each discussion will address the strengths and limitations of the data representation. For each of the data-sets, the applications that can reasonably employ the data-set will be discussed (e.g., model development/validation/application, theory development, performance-based analysis, etc.), focusing on the ways in which the data can be (mis)used and (mis)applied, and the level of analysis that can be conducted. Each of the data-sets will then be employed in several different application types to demonstrate the consequences of these activities and also the real-world implications of the (mis) application of the data-sets.

This article will therefore discuss how contextual omissions, methods of data collection, and of data representation can influence application activities, and the real-world consequences of such activities. This should be of interest to those collecting data, those using data (either as engineers or scientists), and those making use of the structures produced as a consequence.

Session: Data Collection (Pedestrian)

Data Collection (Pedestrian)
Chaired by: Erica Kuligowski

New Data for Human Performance in Planar Corridors
Andreas Winkens, Wolfram Klingsch, and Armin Seyfried

Influence of Geometry Parameters on Pedestrian Flow through Bottleneck
Tobias Rupprecht, Wolfram Klingsch, and Armin Seyfried

Real-Time Video Analysis of Pedestrians to Support Agent Simulation of People Behavior *Olaf Junker, Verena Strauss, Ralph Majer, and Norbert Link*

Free Walking Speeds on Stairs: Effects of Stair Gradients and Obesity of Pedestrians
Taku Fujiyama and Nick Tyler

New Data For Human Performance In Planar Corridors

A. Winkens[1] and W. Klingsch[1] and A. Seyfried[2], [1]Institute for Building Material Technology and Fire Safety Science, University of Wuppertal and [2]Jülich Supercomputing Centre, Forschungszentrum Jülich GmbH

Design of escape routes by human performance data depends on flow rates given by e.g. the maxima of the flow - density relation. Although there are many different studies about this relation, even so for the qualitative shape there is still no accordance. To enhance the empirical database we performed experiments with up to 107 test persons under laboratory conditions to get actual data of local densities, speeds and flow in planar corridors. Due to new methods of digital image processing our analysis is based on data (trajectories) of very high accuracy. Thus we are able to present new insights into the relations between density, speed and flow.

In this contribution we present an extract of our current studies concerning speed, density and flow in planar corridors. We also show effects of different measurement procedures on the results.

Moreover we used six different shapes of measurement areas to point out the influence of this parameter. For the mean value of the speed and flow there are differences up to 100% when fluctuations are not considered.

In this contribution we focus on the results of experiments in planar corridors. In total there were three experimental-setups (see Figure 1) with different widths of the corridor (b=0.7m; b=0.85m; b=1.0m) and different numbers of people ($14 \leq N \leq 107$). All together we performed 29 runs over three days. At a width of b=0.7m just single file movement was possible, the wider setups also allowed movement of people side-by-side. The test persons were evenly distributed inside the setup. An overview of all experiments performed in this series is given in [1]. With the help of industrial cameras and special software tool trajectories with high accuracy [2] could be extracted in the region of interest (see figure 1).

By the use of these exact trajectories we are able to analyse the data inside the region of interest concerning local pedestrian density, speed and flow.

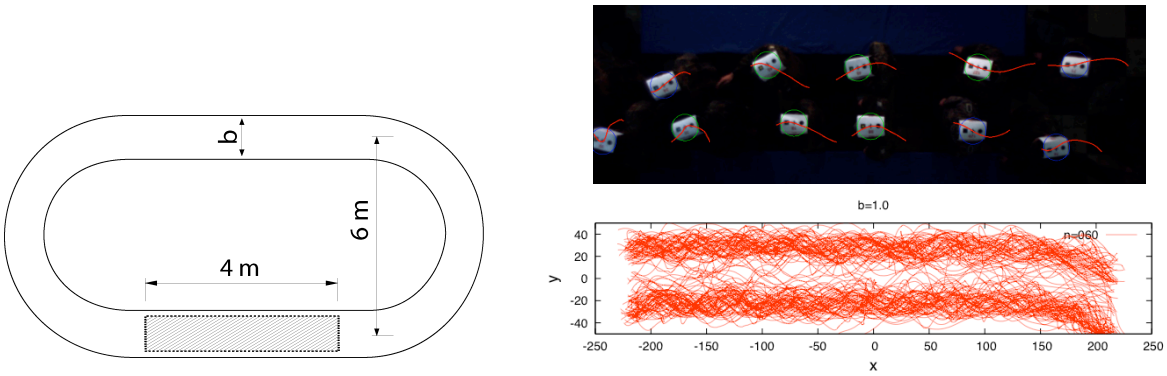


Figure 1: Experimental setup; <u>left:</u> layout; <u>top right:</u> snapshot of experiment (b=1.0m, N=60); <u>down right:</u> trajectories of experiment (b=1.0m, N=60)

We will show influences of chosen measurement areas on resulting values of speed, density and flow. Due to different corridor-widths the measurement area had to be adjusted, too. So, this analysis is another approach to explain differences in several studies of pedestrian movement. Thereby our study also represents an enlargement of the fundamental database for macroscopic data of pedestrian movement. Furthermore we show influences of chosen method of measurement for flow on resulting values.

We will also show dependencies of density and speed on time (see figure 2) as well as the relation between flow and speed, resp. flow and density.

During the experiments we measured local densities up to 8 Persons/m^2 and speeds up to 1.6 m/s (see figure 2). Hence we will present some new data for human performance.

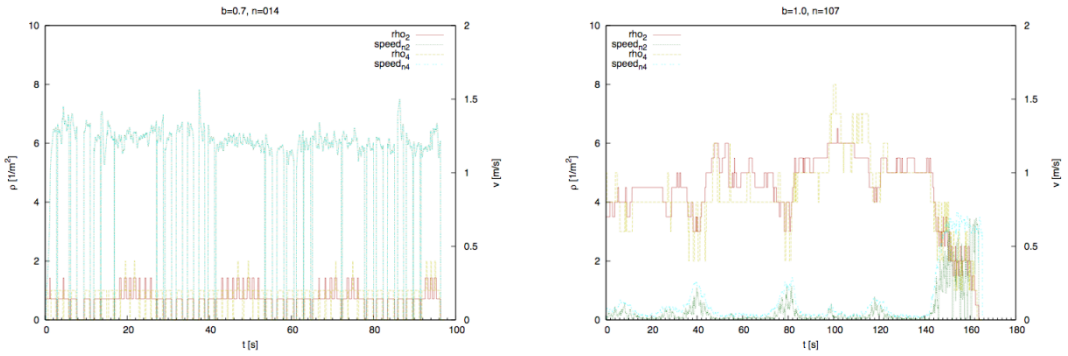


Figure 2: Examples of time-dependence of speed and density; left: corridor width b=0.7m, N=14; right: corridor width b=1.0m, N=107

References

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[2] M. Boltes et al.: Automatic Extraction of Pedestrian Trajectories from Video Recordings; Pedestrian and Evacuation Dynamics 2008; Springer, 2010

Influence of Geometry Parameters on Pedestrian Flow Through Bottleneck

T. Rupprecht[1] W. Klingsch[1] and A. Seyfried[2], [1]Institute for Building Material Technology and Fire Safety Science, University of Wuppertal, Germany and [2]Jülich Supercomputing Centre, Forschungszentrum Jülich GmbH

In pedestrian evacuations bottlenecks can be a crucial factor influencing the evacuation time. The main question involves the design of bottlenecks to enable unhindered pedestrian flow in order to optimize evacuation times. For better understanding of this problem, a set of experiments with pedestrians in different bottleneck-scenarios has been performed. The results enlarge the database and allow the testing of the basic assumptions of performance based egress design.

Within experimental series of evacuation trials the main focus is on two subjects of pedestrians flow dynamics: The fundamental diagram and bottleneck. In the following we present the bottleneck trials. The pedestrian experiments have been performed in well-controlled laboratory conditions. Special attention was given to the comparability of different experimental series because both variations of width and length of the bottleneck have an influence. Formation of lanes inside the bottleneck becomes less pronounced for wide bottlenecks, even for narrow bottlenecks the numbers of lanes don't interfere with the linear relations between flow and bottleneck width. Based on the length of the bottleneck the behavior of pedestrians is different, going through a tunnel or a door. Short bottlenecks show strong non-stationarity.

Real-Time Video Analysis of Pedestrians to Support Agent Simulation of People Behavior

O. Junker[1], V. Strauss[1], R. Majer[1], N. Link[2], [1]Vitracom AG and [2]Airport Research Center GmbH

Online simulation coupled with real-time measurements of pedestrians in public buildings is a novel application which can be used to increase the security and safety of pedestrians within those buildings. To receive realistic forecasts it is necessary to update the simulation constantly against reality. The real-time video analysis can thereby support the simulation with the necessary data. This proposed system is largely supported by the state observer of the control theory.

Within a laboratory one room model pedestrian behavior is monitored and analyzed by video cameras. Evolving data is subsequently provided for the simulation where flow rates are additionally recorded. Thus, two resulting passenger flow rates are available which can be compared by the simulation controller. The actuators, receiving information from the controller, can afterwards trigger an appropriate action. Two different actuators have been realized in the model in order to bring the simulation passenger flow closer to the observed passenger rates: the velocity controller adjusts the walking speed of the passengers and the flow generator actuator has the ability to match the passenger generation rate.

Results show that the simulation passenger flow curve converges to the real passenger flow. As expected, the simulation curve follows the real passenger rate with a certain delay. Nevertheless, the simulation model appears to reflect the behavior of the persons in an appropriate way. Further investigations will show which additional instruments can be used to refine the simulation actor behavior.

Session: Data Collection (Vulnerable Groups)

Data Collection (Vulnerable Groups)
Chaired by: Rita Fahy

Travel Along Stairs by Individuals with Disabilities: A Summary of Devices Used During Routine Travel and Travel During Emergencies
Glenn Hedman

The Evacuate Training Problems of Earthquake In China
ChunXia Lu

An Experimental Evaluation of Movement Devices Used to Assist People With Reduced Mobility In High-Rise Building Evacuations.
Ton Adams and Edwin Galea

Evacuation Dynamics of Children –Walking Speeds, Flows Through Doors In Day-Care Centres
Aldís Rún Lárusdóttir and Anne Simone Dederichs

Travel Along Stairs By Individuals With Disabilities: A Summary of Devices Used During Routine Travel and Travel During Emergencies

Glenn Hedman, University of Illinois at Chicago

Many devices exist which are designed to enable individuals with disabilities to travel between floors via staircases. The range of devices includes wheelchairs that descend and ascend stairs, platforms and chairs installed on the staircase, wheelchair carriers which transport the individual while occupying a wheelchair, and evacuation chairs used during emergencies.

A summary of commercially-available devices is presented, categorized by de-sign type and usage. Specifications are provided for characteristics such as overall size, device weight, travel speed.

A summary of existing international standards and testing methods which apply to these devices is presented. A description of standards development work in the area of emergency evacuation chairs is also included.

The Evacuate Training Problems of Earthquake In China

Chunxia Lu, School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiaotong University

WenChuan Earthquake took place on May 12, 2008 in China. 69,227 were confirmed dead, but Shangzao junior high school was a miracle. There was no death or injured. It took over two thousand students and teachers only one minute and thirty-six seconds to evacuate safely from the two 5-floor buildings. One of the miracle resulted from their continuous evacuating training every semester. The paper summarized the evacuating experience of Shangzao junior high school firstly. Other trainings from high school to elementary school were analyzed after the earthquake. Be short of the guidance and organizations, there were some problems in the trainings. Speed should be focused as the No.1. Order is the most important especially in elementary school. Students should be told to run downstairs in two line if the stairs were not wide enough. It was dangerous for students to put books on their heads while they ran down, because it led to tumble easily.

An Experimental Evaluation of Movement Devices Used to Assist People With Reduced Mobility In High-Rise Building Evacuations

A.P.M. Adams and E.R. Galea, Fire Safety Engineering Group, University of Greenwich

Evacuating People with Reduced Mobility (PRM) from multi-storey buildings can be a difficult task. A number of commercially available devices can be used to assist in moving the PRM to the ground however, there is little consistent data quantifying the relative performance of these devices. In this paper four commonly used assist devices, the Evac+Chair, Carry-Chair, Stretcher and Drag Mattress are used in a series of 32 evacuation trials designed to assess their performance. The trials involve moving a PRM from a wheelchair to the device, moving the PRM along a long corridor to a stair and then down 11 floors to the ground. The performance of the devices is then assessed in terms of travel speed on the flat and stairs, number of handlers required to operate and ease of overtaking by other stair users.

Evacuation Dynamics of Children – Walking Speeds, Flows Through Doors In Daycare Centers

A. R. Larusdottir and A. S. Dederichs, Department of Civil Engineering, Technical University of Denmark

The purpose of this study is to deliver new data and to bring attention to the subject of evacuation of children. Evacuation characteristics such as flow, densities and walking speeds are in focus. Current literature on evacuation is based mostly on studies on adults. Ten Danish daycare centers participated in full scale evacuation experiments where two age groups 0-2 years and 3-6 years were analyzed separately. The overall findings were as follows. Flow through doors, walking speeds and densities were age-dependent and differed strongly from the data in existing literature. The results showed higher walking speeds in spiral stairs when the children were familiar with the evacuation path. Higher person densities and faster flow through doors were obtained among the children than found in the current literature on adults. Children in the younger age group were generally slower than the older children. The children walked slower in horizontal plane than adults, however they were keen to run during the evacuations, in the latter case their travel speed increased and exceeded the adults'. Since the evacuation characteristics of children differ in many ways from those of adults, nowadays models badly comprehend the evacuation behavior children.

Session: Theory for Models

Theory for Models
Chaired by: Norman Groner

Pre-Warning Staff Delay: A Forgotten Component in ASET/RSET Calculations?
Steven Gwynne, Dave Purser, Dave Boswell and Erica Kuligowski

Fundamental Diagrams for Pedestrian Networks
Serge Hoogendoorn, Mario Campanella and Winnie Daamen

Modeling of Human Behavior in Crowds Using a Cognitive Feedback Approach
Yiannis Papelis, Lisa Bair, S. Manepalli, Poornima Madhavan, Rani Kady and E. Weisel

How do People with Disabilities Consider Fire Safety and Evacuation Possibilities in Historical Buildings?
Staffan Bengtson, Lena Kecklund, Elena Siré, Kristin Andrée and Sara Willander

Pre-Warning Staff Delay: A Forgotten Component In ASET/RSET? Calculations

Steven Gwynne, Dave Purser, Dave Boswell and Erica Kuligowski

Increasingly, a performance-based approach is adopted to demonstrate the safety level of a structure and procedure in response to a fire. This requires a comparison between the time available (available safe egress time – ASET) and the time required for the population to reach safety (required safe egress time – RSET). Various methods are used to make this comparison including engineering calculations and computational tools. This article addresses a potential limitation in the typical RSET calculation that might lead to this value being underestimated in certain situations, and then not represented in the engineering calculations and computational tools applied.

It is now widely accepted that a key component in the time to reach safety is the pre-evacuation time: the time between the occupants being notified (or becoming aware) of an emergency and initiating purposive egress movement toward a place of safety. Depending on the nature of the occupancy, the scenario, the procedure and the population this time can represent the majority of the time to reach safety; e.g. in hotels where the occupants may be asleep.

Traditionally, the RSET calculation moves from the time of ignition, to the time for detection, to the time of warning and then to the time for occupant response: occupants then perceiving a cue, interpreting it, deciding to act and then moving to a place of safety. This is further simplified during the engineering process. In some instances once ignition has been detected the alarm is raised and evacuation can begin as soon as possible. For instance, in a small domestic residence once a fire is detected by a (functioning) smoke detector the alarm will sound. However, in more complex structures/ scenarios (such as transport terminals, large hotels, high-rise structures, etc.), more sophisticated emergency procedures involving staff activities are often in place. These procedures often require the initial notification of staff without notifying the general population (often referred to as private mode) and the confirmation of the incident by the staff prior to the general population being notified. Pivotal in this type of procedure is the reaction and performance of the staff. This is often appropriate in occupancies where an evacuation would seriously disrupt operations and may pose security risks; e.g., a hospital, an airport, etc.

Although it has been identified as a key component of warning time within RSET [3], the time for the staff to go through the decision-making process is often currently omitted. Time for decision making is often only currently represented for the general population (i.e., the evacuating occupants). Staff decision-making may occur in a number of situations; e.g., in discovering a fire, interpreting cues first hand and recognizing them as indicating a real incident, or being notified of an incident (i.e., via the notification system at the fire panel, by other members of staff, by members of the occupant population, etc.). In these instances, staff members will need to perceive, interpret, decide on an action, and then perform the action – in much the same way as other occupants; all of which may take time. Although trained staff may be expected to go through this process more quickly, they would still have to go through it, delaying their response and in turn, the response of the general population of the building.

A delay in staff decision-making and response has been identified as a problem in previous incidents [1,2]. In a number of major multi-fatality fire incidents, staff is known to have been aware of the fire some time before a general alarm was raised to instigate evacuation of building occupants. In addition, similar issues have occurred in the response to security breaches and subsequent staff response; e.g., universities, schools, hospital premises, etc.

In a typical example of this type of system, automatic detection of a fire results in an immediate pre-alarm to a location such as a security room or hotel reception desk. This is followed by a delay until the operative perceives/recognizes the alarm and decides what action is required. There is then a response period during which the operative takes action. The first action is likely to involve some form of investigation to confirm the information requiring examination of the alarm panel, followed by investigation at the location of the alarm either in person or by contacting another staff member (for example by radio). Having arrived at the location of the fire, the staff member investigating then needs time to appraise the situation and report back, after which a further period is required for possible consultation and consideration before instigating a general evacuation alarm to affected building occupants. Even if a member of staff discovers the incident firsthand (i.e., is not subject to the communication process described above), they will still have to go through the same decision-making process as a member of the general public before reporting the incident. This action will lead to a general alarm or warning, commencing the decision-making process of the general population. The delay may then be due to procedural actions, cognitive processes, or both. In this discussion, we have focused on the delays introduced by the decision-making process. This delay may be prolonged by having to travel to the scene of the incident and the time taken to perform actions. For some alarms systems there is a time-out delay following the pre-alarm, allowing a fixed maximum time for the staff to investigate the incident, after which a general alarm is sounded unless the pre-alarm is cancelled. Although this provides some back-up, it still increases the delay before a general alarm, and there is a temptation for staff to cancel the pre-alarm before investigating. Alarms systems may also produce a pre-alarm on triggering of a single detector, but default to a general alarm if two detectors are triggered, so that a large fire should automatically trigger a general alarm. Again, such a system does introduce a delay in the time from first detection to general alarm.

An important aspect of this kind of situation is that a staff member receiving a pre-alarm, or even after discovery of an early growing fire, is likely to be unwilling to instigate a general evacuation of a large facility, such as an airport check-in hall, unless they are *convinced* the situation is serious. This may be due to issues of disruption, security and/or safety, and their delay can result in a reduction of the time available for the general population of the building to escape.

In this article, the Pre-Warning (warning time) concept is developed: the time between the fire being noted by staff and the raising of a general alarm. This represents the potential delay in staff response as they react to the provision of cues and respond – a delay that may be procedural and/or cognitive. The theoretical basis of this concept is discussed, examples of incidents where this was a factor are described, and data provided from experiments and incidents to quantify the extent of the impact and the effect of this concept upon the ASET/RSET calculation is discussed. Hypothetical examples of how Pre-Warning delay can influence RSET will be presented, along with a discussion of which procedures are particularly susceptible to the delay, and suggestions as to how this might be remedied. By better understanding this phenomenon, a more accurate representation of the RSET process and a better understanding of the strengths and limitations of procedural responses should be possible. These can then be better represented in the engineering calculations and computational tools employed, allowing for more credible and reliable analysis to be conducted.

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Macroscopic Fundamental Diagrams For Pedestrian Networks In Different Conditions

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Recent work (Daganzo and Geroliminis, 2008) has shown that for (homogeneous) traffic networks, aggregate network dynamics can be described by a single relation: the Macroscopic Fundamental Diagram (MFD). This MFD relates average flow variables such as average performance (weighted flow), flow, or speed, to aggregate quantities, such as the average density or number of vehicles in the network (accumulation). The MFD has a strong significance, from the viewpoint of performance identification of networks, from the viewpoint of network traffic management (e.g. perimeter control; see Geroliminis and Daganzo, 2008), etc.

In this paper we set out to establish a similar relation for two-dimensional pedestrian flows. In doing so, we investigate whether the average performance of the area (building, railway station, mall, etc.) can be explained sufficiently well by the total number of pedestrians in the area. To establish this, we analyze both empirical data from pedestrian experiments and synthetic data generated by a microscopic pedestrian flow model.

It turns out that the MFD can indeed also be established for walking areas. In doing so, we are able to identify the network load which will be critical from a performance point of view. In other words, we can pinpoint a critical accumulation n_{crit} that describes the boundary accumulation after which the network performance will start to deteriorate with increasing accumulation. For some specific areas, the performance does not deteriorate but will remain constant until some even higher accumulation n'_{crit} is reached.

The notion of the MFD for pedestrian flows has a strong significance, for instance for determining the Level-of-Service (LoS) for an area, from the perspective of aggregate flow modeling (coarse dynamics), and from the perspective of crowd-control. All these aspects will be presented briefly in the paper.

The first situation that we will consider is a simple bottleneck scenario. The data stem from a large scale walking experiment in which we analyzed the pedestrian walking behavior in case of a narrow corridor of 1 m width. As time progresses, the narrow bottleneck becomes oversaturated and congestion will occur upstream of the bottleneck. When the accumulation in the area increases, the average speed decreases (as is expected). The generalized flow first increases as the accumulation increases, but once a critical accumulation level is reached (approx. 12.5 pedestrians) the generalized flow becomes a constant value of approximately 1.2 P/m/s, which is the capacity of the bottleneck. For this single bottleneck scenario, no performance degradation is expected when the network accumulation is overcritical. Since there is no spillback or gridlock effect expected, the capacity of the narrow corridor is the limiting factor. Hence, even if congestion becomes very severe, the flow is equal to the bottleneck capacity. Only in some cases, where the pressure due to the upstream pedestrians causes 'arc formation' in front of the bottleneck (the so-called 'faster-is-slower' effect) we would expect a reduction in the bottleneck capacity.

The second case relates to the results from the bi-directional flow simulation. In this case, we see that for some periods, the flow collapses and the performance reduces. This occurs when the generalized density is larger than approximately 1.5P/m^2. We also see that when the density is sufficiently high (around 4P/m^2) the generalized flow even reduces to (nearly) zero. The relative large amount of scatter in the MFD is remarkable. This can be partially explained by the chaotic nature of the phenomena that occur in

pedestrian flows, in particular of the lane formation process. In many cases, the lane formation process that occurs in bi-directional pedestrian flows causes the flow to remain fluidic and smooth. In some cases, however, the lane formation will (temporarily) break down and a gridlock will occur.

The third situation concerns an MFD of a complex walking area namely the central hall of the Schiphol Airport in Amsterdam also known as Schiphol Plaza. The simulations have been run using the microscopic pedestrian simulation tool Nomad. The Schiphol simulation was based on a realistic scenario developed to simulate one day of pedestrian traffic in the Plaza area. The simulation started with low inflows at 5:00 in the morning and presented a steady increase until 8:00 when a large inflow indicated the beginning of the peak traffic in the area. At this time of the day the inflows mainly originated in the exits of the train platforms inside the court. The original OD tables were kept but the pedestrian inflow values were multiplied by three. This extreme inflow formed three gridlocks. The biggest congestion was caused by the gridlock in the centre court of the Plaza. During the congested period pedestrians walking in areas adjacent from the congestion could freely walk. The MFD shows a clear peak in the generalized flow at approximately 2000 pedestrians. When the number of pedestrians in the area increases further, the performance starts to reduce.

The three examples show that the shape of the MFD reflects the coarse dynamics of the area. It shows if and under which circumstances the performance of the area will deteriorate and to which extent this deterioration will occur. The shape of the MFD is determined by several things: the shape and use of the area, the composition of the pedestrian flow, the OD matrix, the individual pedestrian walking behavior as determined by trip purpose, age, gender, etc. In particular, let us briefly discuss the impact of area function and use.

In the empirical and simulated bottleneck examples, the MFDs are (non-strictly) monotonically increasing functions of the accumulation: when the area fills up, the performance of the area - in terms of generalized flow or outflow - maintains at a certain, steady level. This does not mean that the individual pedestrians do not experience delays. The average speed is decreasing with increasing accumulation. For the bi-directional flow and crossing flow examples we saw that the MFD has a certain maximum flow value at the critical accumulation (or critical density). This means that for such an area, the performance will start to deteriorate when the accumulation is too large. The Schiphol Plaza example is a complex area in which different basic infrastructure elements are combined. We have areas which are typically uni-directional bottlenecks, others which are predominantly bi-directional flow areas, other areas reflect crossing flow situations, etc. The resulting MFD is therefore some sort of a weighted mix of the MFDs of the basic areas. To increase the applicability of MFD's to practical applications, we identify a new characteristic n'_{crit} of a MFD of a pedestrian area. This value identifies the point at which the performance starts to break down. In many cases (the bi-directional flow area, the crossing-flow area, the Schiphol Plaza area) n_{crit} appears to be equal to n'_{crit}. If $n_{crit} < n'_{crit}$, such as in case of a simple bottleneck, an area has storage capacity that may be utilized in for instance crowd control applications.

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Modeling of Human Behavior in Crowds Using a Cognitive Feedback Approach

Y. E. Papelis[1], L. J. Bair[4], S. Manepalli[1], P. Madhavan[2], R. Kady[3], E. Weisel[4], Virginia Modeling Analysis & Simulation Center [1], Dept. of Psychology[2], Dept. of Engineering Management and Systems Engineering[3], Old Dominion University, and WernerAnderson, Inc.[4]

We present a real-time agent-based approach to modeling crowd behavior that is based on complementary psychological and engineering principles. The application focus is for developing realistic models that address not only the physical but also the psychological aspects of crowd behavior. Our approach to modeling the psychology of a crowd is based on the principle of emotional reflection. According to this principle, our emotions are evoked in response to our perception of other people's emotions; hence emotions propagate through a crowd as a result of each person's perception of other crowd member's emotions as well as external factors. The emotional model is coupled with a movement model that is based on the social forces formulation, but with parameters modified to represent the current emotional state of each crowd member. We present the model along with results of how different emotional levels can affect the movement dynamics of crowds.

How Do People With Disabilities Consider Fire Safety and Evacuation Possibilities In Historical Buildings?

Staffan Bengtson, Lena Kecklund, Elena Siré, Kristin Andrée and Sara Willander, Brandskyddslaget AB, MTO Säkerhet AB, and Elena Siré Architect AB

The research of human behaviour in fire has rarely touched the situation for people with disabilities in an evacuation situation. The aim of this study was therefore to investigate how people with activity limitations consider the evacuation possibilities from a cultural building today. This study illustrates how people with different activity limitations experience the evacuation environment from their perspective.

The study had an explorative approach to raise the knowledge about past experience, needs and wishes that people with different disabilities have in cultural buildings. A qualitative method was used to be able to get the information. The main focus was on getting to know if there were any differences between groups with different disabilities. The data were collected through four focus groups. Each group consisted of people with the same kind of disability. The different types of activity limitations that were represented in this study were; mobility impairment (non-wheelchair users and wheelchair users), visual impairment and auditory impairment. The age range for the participants varied between 20-70 years. It was also a mixture between male and female. The participants had to be persons that frequently visit historical buildings.

After analysing the results the main finding was that there are shortcomings in the physical environment but especially in how to organize the evacuation. The participants had past experiences of being left behind in an evacuation situation. There are also problems when it comes to how to give the evacuation information to the disabled persons. The problem is that they often need to be given the information in a different way. For example a person that is visually impaired would prefer to have a model to sense instead of looking on an evacuation map. Other main problems for the participants was to know how the handle on an emergency door worked, and that they were often placed too high for a wheelchair user to open the door easily. They wished that there was a standard for this so that they easy could open the door by them self.

This study was quite small but it clearly shows the need of knowledge in this area of research so that there can be standards for how to design emergency routs for people with disabilities. It is of importance that this knowledge will be spread to architects and people working in historical buildings. In historical buildings the staff needs to be aware of that people with impairment count on their support in an evacuation situation. Therefore it is important that the staff is trained and that there is an organization to handle evacuation situations. It is important that this type of information is taken in to consideration in the future in the designing process of public buildings.

Session: Data Collection (Transport)

Data Collection (Transport)
Chaired by: Richard Peacock

Evacuation Analysis of 1000+ Seat Blended Wing Body Aircraft Configurations: Computer Simulations and Large-Scale Evacuation Experiment
Edwin Galea, Lazaros Filippidis, Zhaozhi Wang, Peter Lawrence, and John Ewer

Collection of Evacuation Data for Large Passenger Vessels at Sea
Edwin Galea, Robert Brown, Lazaros Filippidis and Steven Deere

Experimental Research on Investigation of Metro Passenger Evacuation Behaviors in Case of Emergency
He Li, Zhong Maohua, Shi Congling, Shi Jiehong, Chen Haicheng and Xu Qiaoxiang, Chen Haicheng and Xu Qiaoxiang

Modelling Random Taste Variations on Level Changes in Passenger Route Choice in a Public Transport Station
Irmgard Zeiler, Christian Rudloff and Dietmar Bauer

Evacuation Analysis of 1000+ Seat Blended Wing Body Aircraft Configurations: Computer Simulations and Full-Scale Evacuation Experiment

E. R. Galea, L. Filippidis, Z. Wang, P. J. Lawrence and J. Ewer, Fire Safety Engineering Group, University of Greenwich

Blended Wing Body (BWB) aircraft with around 1000 passengers and crew are being proposed by aircraft manufacturers. This type of aircraft configuration is radically different from conventional tube type passenger aircraft and so it is essential to explore issues related to both fire and evacuation for these configurations. Due to both the large size and the unusual nature of the cabin layouts, computer simulation provides the ideal method to explore these issues. In this paper we describe the application of both fire and evacuation simulation to BWB cabin configurations. The validity of the computer evacaution simulations is also explored through full-scale evacuation experiments.

Collection of Evacuation Data for Large Passenger Vessels at Sea

E.R. Galea[1], R.C. Brown[1,2], L. Filippidis[1], and S. Deere[1], [1]Fire Safety Engineering Group, University of Greenwich and [2]Offshore Safety and Survival Centre, Fisheries and Marine Institute, Memorial University

In the past decade, significant effort has gone into the planning and execution of full-scale sea trials in an attempt to improve, calibrate and validate existing evacuation models for passenger ships. In September, 2009 two assembly exercises were conducted at sea onboard the RO-PAX ferry SuperSpeed 1 by team members of the EU-funded project SAFEGUARD. The exercises were conducted with passengers during routine sailings between the ports of Kristiansand, Norway and Hirtshals, Denmark. Between both trials, a total of 1,769 passengers were assembled, on day one, 902 passengers and on day two 867 passengers. As part of the data collection exercise, passenger response time data was collected – using video cameras – and passenger movement data was collected using a novel infra-red (IR) based position logging system. This paper briefly describes the development and testing of the data acquisition system and briefly discusses preliminary results.

Experimental Research on Investigation of Metro Passenger Evacuation Behaviors in case of Emergency

He Li[1,2], Zhong Maohua[1], Shi Congling[1], Shi Jiehong[1,2], Chen Haicheng[1] and Xu Qiaoxiang[3], [1]China Academy of Safety Science and Technology, [2]University of Science and [3]Nanjing Metro Co., Ltd.

As traffic problems in major and medium cities of China are getting increasingly serious and the demands for public transit are rising dramatically, the construction of subways and light-rail transit systems is imperative in the construction of infrastructures in various major cities and is also the symbol of modernized metropolitans. The total length of subway to be built and completed in China by 2010 is 1200 km. However, the social influence would be great once the emergency occurs in metro. To realize and grasp the characteristics of evacuation behavior of passengers in metro emergency is the precondition for the operation enterprise to constitute effective planning of emergency evacuation and conduct the passengers' evacuation to safe area reasonably and quickly. The discrepancy in economy, culture, population and number of operational subway routes in different cities are bound to result in different passenger evacuation characteristics in case of any subway emergency. In this article, by questionnaire survey method and statistical analysis method, an investigation was conducted on the safety awareness and safe evacuation behavior of subway passengers in three different regions in China, namely Beijing (BJ),Nanjing (NJ) and Guangzhou (GZ), based on which the characteristics of subway passengers evacuation behavior in these cities were analyzed.

Modelling Random Taste Variations on Level Changes in Passenger Route Choice in a Public Transport Station

I. Zeiler, C. Rudloff and D. Bauer, Austrian Institute of Technology

In large stations of public transportation high crowd densities can lead to potential safety risks and to unnecessary delays. To assess the *actual* capacity of potential bottlenecks a deeper understanding on the route choice of pedestrians is of great importance. This paper investigates the factors that influence the route choice of pedestrians when facing a stair/escalator combination in a major Austrian train station. We employ random utility models on data sets of revealed and stated preferences. In particular we investigate the potential for heterogeneities in taste by employing *mixed logit models*. The results show that, first, crowding is an important factor for route choice, second, that the application of mixed logit models is appropriate and, last, that the use of both revealed and stated preference data adds valuable information.

Session: Data Collection Methods

Data Collection Methods
Chaired by: Jake Pauls

Extended Range Telepresence for Evacuation Training in Pedestrian Simulations
Antonia Pérez Arias, Uwe D. Hanebeck, Peter Ehrhardt, Stefan Hengst, Tobias Kretz and Peter Vortisch

Proof of Concept: Use of Eye Tracking to Record How People Use Exit Signage
Robert Till and Jason Babcock

Measurement Techniques For Unannounced Evacuation Experiments
Daniel Nilsson and Håkan Frantzich

Automation of Pedestrian Tracking in a Crowded Situation
Saman Saadat and Kardi Teknomo

Extended Range Telepresence for Evacuation Training in Pedestrian Simulations

A. Pérez Arias[1] and U. D. Hanebeck[1], P. Ehrhardt[2], S. Hengst[2], T. Kretz[2], and P. Vortisch[2,]
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In this contribution, we propose a new framework to evaluate pedestrian simulations by using Extended Range Telepresence. Telepresence is used as a virtual reality walking simulator, which provides the user with a realistic impression of being present and walking in a virtual environment that is much larger than the real physical environment, in which the user actually walks. The validation of the simulation is performed by comparing motion data of the telepresent user with simulated data at some points of the simulation. The use of haptic feedback from the simulation makes the framework suitable for training in emergency situations.

Proof of Concept: Use of Eye-Tracking to Record How People Use Exit Signage

R. C. Till and J. S. Babcock, John Jay College of Criminal Justice and Positive Science, LLC

To date, there is little research concerning selection of exit paths in emergency and non-emergency situations. Whether an individual takes their cues from others, follows signs, uses some other unknown method or some combination of the three when navigating unknown structures needs clarification. We used a wearable eye-tracking system to record where subjects look when they are exposed to new environments to determine how they use their visual awareness to navigate, and whether they are using exit signage to do so. The system provides a video record of the subject's point-of-view. This knowledge could ultimately help improve evacuation times and save lives during emergencies by allowing for better design of egress systems and/or models, particularly those where a subject has no prior knowledge of the layout of the structure, such as an office building, subway/rail station, or an airport.

Measurement Techniques for Unannounced Evacuation Experiments

D. Nilsson and H. Frantzich, Department of Fire Safety Engineering and Systems Safety, Lund University

There are many available measurement techniques for documenting people's movement patterns, but not all of them are appropriate for unannounced evacuation experiments. An unannounced evacuation requires that participants are not influenced beforehand. In addition, experiments are performed in all types of buildings and low ceiling height is often a problem. This paper describes three techniques that can be used for unannounced evacuation experiments, namely (1) filming from above – cameras with wide angle lenses, (2) triangulation with two cameras, and (3) distance measurement with a laser scanner. The description is based on the results from a research study in which the three measurement techniques were tested and evaluated. The study also involved collection of data in unannounced evacuation experiments.

Automation of Pedestrian Tracking in a Crowded Situation

S. Saadat and K. Teknomo, Ateneo De Manila University

Studies on microscopic pedestrian requires large amounts of trajectory data from real-world pedestrian crowds. Such data collection, if done manually, needs tremendous effort and is very time consuming. Though many studies have asserted the possibility of automating this task using video cameras, we found that only a few have demonstrated good performance in very crowded situations or from a top-angled view scene. This paper deals with tracking pedestrian crowd under heavy occlusions from an angular scene.

Our automated tracking system consists of two modules that perform sequentially. The first module detects moving objects as blobs. The second module is a tracking system. We employ probability distribution from the detection of each pedestrian and use Bayesian update to track the next position.

The result of such tracking is a database of pedestrian trajectories over time and space. With certain prior information, we showed that the system can track a large number of people under occlusion and clutter scene.

Session: Large-scale Modeling

Large-scale modeling
Chaired by: Weiguo Song

Runtime Optimization of Force Based Models within the Hermes Project
A. Seyfried, M. Chraibi, U. Kemloh, J. Mehlich and A. Schadschneider

A Dynamic Simulation on Crowd Congestion in Large-Scale Terminal Station Complex in an Official Announcement Advisory Information
Qing-Lin Cui, Manabu Ichikawa, Toshiyuki Kaneda and Hiroshi Deguchi

Evacuation Assistance for a Sports Arena Using a Macroscopic Network Model
Andreas Schomborg, Klaus Nökel and Armin Seyfried

Validation of the Potential-based Evacuation Model of City Residents in Post-earthquake Fire
Tomoaki Nishino, Shin-ich Tsuburaya, Keisuke Himoto and Takeyoshi Tanaka

Runtime Optimization of Force Based Models within the Hermes Project

A. Seyfried[1], M. Chraibi[1], U. Kemloh[1], J. Mehlich[1] and A. Schadschneider[2], [1]Jülich Supercomputing Centre, Forschungszentrum Jülich GmbH and [2]Institut für Theoretische Physik, Universität zu Köln

The aim of the Hermes project is the development of an evacuation assistant to support security services in case of emergency in complex buildings and thus to improve safety at mass events. One goal of the project is to build models for pedestrian dynamics specifically designed for forecasting the emergency egress of large crowds faster than real-time using methods applied in high performance computing. We give an overview of the project and the modeling approaches used focusing on the runtime optimization and parallelization concepts.

A Dynamic Simulation on Crowd Congestion in Lange-Scale Terminal Station Complex in an Official Announcement Advisory Information

Qing-Lin CUI [1] Manabu ICHIKAWA[2] Toshiyuki KANEDA [1] and Hiroshi DEGUCHI[2], [1] Graduate School of Engineering, Nagoya Institute of Technology and [2] Interdisciplinary Graduate School of Science and Engineering, Tokyo Institute of Technology

On the assumption of advisory information concerning an imminent Tokai earthquake being officially announced, as a case example we developed a spatial-spot type agent-based simulation model for the Nagoya Station area, where several terminal stations are concentrated; in the model, agents played people on their way home, and such factors as the routes selected by agents and the spatial restrictions, e.g. passages, were taken into consideration. Basic on SOARS(Spot Oriented Agent Role Simulator)platform, we conducted a large-scale crowd simulation with 160,000 agents and analysis the change of space density in one hour to compare to the estimates given by Nagoya City, we analysis the result and also refer to this kind of project for implementing much higher functions.

Evacuation Assistance for a Sports Arena Using a Macroscopic Network Model

Andreas Schomborg[1], Klaus Nökel[2] and Armin Seyfried[3], [1,2] PTV Planung Transport und Verkehr AG and [3] Forschungszentrum Jülich GmbH (JSC)

The macroscopic network model for pedestrians described in this paper is part of the German research project Hermes. The purpose of Hermes is the development of an evacuation assistant. Key outputs of the network model are travel (evacuation) times, identification of bottlenecks, pointing out alternative escape routes and/or optimization of escape route usage. The model uses Dynamic User Equilibrium (DUE) to analyse the network. This way it is able to show pedestrian flow with transient congestion effects, leading to time-varying route choice during an evacuation. The results can be calculated before or during an emergency case. The calculation time is much shorter and the results can be shown quicker than with a common microsimulation movie or animation. But arguably a microsimulation can be more detailed and for absolute information like evacuation time more conventional.

Validation of a Potential-based Evacuation Model of City Residents in Post-earthquake Fire

T. Nishino, S. Tsuburaya, K. Himoto and T. Tanaka, Disaster Prevention Research Unit, Kyoto University

Evacuation of a large number of residents is conceivable in case of urban fires following a large earthquake in a city. It is essential to implement effective evacuation measures for ensuring residents' safety in the regional disaster prevention plan. We have been developing a simulation model based on a potential method for the evacuation behaviors of city residents in a post-earthquake fire. The model has been validated by comparing the evacuation behaviors of Tokyo City residents in the Kanto Earthquake Fire, where the distribution of fatalities calculated by this model was qualitatively similar to that reported by the survey of that time. In this paper, the evacuation behaviors of Tokyo City residents in the Kanto Earthquake Fire were simulated for validating the prediction function of this model in terms of the traveling trajectory of an evacuee.

Session: General Model Development (1)

General Model Development (1)
Chaired by: Ed Galea

Risk Minimizing Evacuation Strategies Under Uncertainty
Gregor Lämmel, Hubert Klüpfel and Kai Nagel

Methods for Improving Efficiency of Queueing Systems
Daichi Yanagisawa, Yushi Suma, Yuki Tanaka, Akiyasu Tomoeda, Kazumichi Ohtsuka and Katsuhiro Nishinari

*A Stochastic Evacuation Model for Fire Life Safety Assessment in Transportation System
Kai Kang

Cellular Automata Evacuation Model Considering Information Transfer in Building with Obstacles
Kongjin Zhu, Lizhong Yang and Shaobo Liu

Risk Minimizing Evacuation Strategies under Uncertainty

G. Lämmel[1] and H. Klüpfel[2] and K. Nagel[1], [1]Technische Universität and [2]TraffGo HT GmbH

This paper presents results on the simulation of the evacuation of the city of Padang with approximately 1,000,000 inhabitants. The model used is MATSim (www.matsim.org). Three different strategies were applied: shortest path solution, user optimum, system optimum, together with a constraint that moves should reduce risk whenever possible. The introduction of the risk minimization increases the overall required safe egress time (RSET). The differences between the RSET for the three risk minimizing strategies are small. Further quantities used for the assessment of the evacuation are the formation of congestion and the individual RSETs (in comparison with the available SET).

Methods for Improving Efficiency of Queuing Systems

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We have considered the methods for improving efficiency in queuing systems by theoretical analysis and experiments. First, a queuing system which has plural service windows is studied. There are mainly two kinds of systems which are a parallel-type queuing system and a fork-type queuing system. Queuing theory is often used to analyze these queuing systems; however, it does not include the effect of walking distance from the head of the queue to service windows; thus, a walking-distance introduced queuing theory is investigated. By using this model, we have discovered that the suitable type of system changes according to the utilization of the system. We have also verified that when we keep one person waiting at each service window in the fork-type queuing system, the waiting time dramatically decreases. Secondly, we consider queuing systems in amusement parks. Plural people waiting in the queue move to get on a roller coaster at the same time; therefore, the efficiency of the system is improved by shortening the moving time. The result of the experiments indicates that the moving time decreases if people keep walking in the queue to start instantaneously.

A Stochastic Evacuation Model for Fire Life Safety Assessment in Transportation System

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This paper presents a stochastic model for emergency evacuation simulation such as for a subway station. The model, MCEVAC was developed using Monte Carlo and a macro-simulation technique; the model includes a number of random variables, such as occupant load, initial occupant load, and pre-evacuation time. A random event of a train fire including fire location, fire growth rate, and the effects of fire smoke, can be used to determine the accessibility of egress paths. As model output, a probability representation of the evacuation time can be obtained by taking into account all or selected random variables. For validation, the calculated exiting time shows agreement with that from a previous station evacuation study. For a hypothetical train fire, the predicted evacuation time consists of likely consequences of the required safe evacuation time in the form of a statistical distribution. While still under development, the model is expected to be used for performance-based fire safety design of transit stations and tunnels.

Cellular Automata Evacuation Model Considering Information Transfer in Building with Obstacles

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The buildings are usually divided into two categories in light of whether obstacles exist: the large space with no obstacles (C-type buildings) and the complex buildings with lots of obstacles (L-type buildings). In this paper, considering the aisle region attraction factor, we proposed a revised model which is suitable to simulate the evacuation process in the L-type buildings (such as classroom, theater, and stadium bleacher) based on our original cellular automata occupant evacuation model. Furthermore, the revised model is able to implement the function that transfers real time information of the occupant density at exit area to evacuees. At last, a case study of simulation evacuation process in a theatre was proposed.

Session: Transport modeling

Transport modeling
Chaired by: Hubert Klupfel

Assistance of Evacuation Planning with High-Speed Network Model-based Pedestrian Simulator
Tomohisa Yamashita, Shunsuke Soeda and Itsuki Noda

An Evacuation Model for High Speed Trains
Jorge Capote, Daniel Alvear, Orlando Abreu, Mariano Lázaro, and Arturo Cuesta

Comparison of a Grid-based and Continuous Space Pedestrian Model: Analysis of Normal Operations and Evacuation at a Train Station
Christian Castle and Nicholas Waterson

Assistance of Evacuation Planning with High-Speed Network Model-based Pedestrian Simulator

Tomohisa Yamashita, Shunsuke Soeda, and Itsuki Noda, Information Technology Research Institute (ITRI), and National Institute of Advanced Industrial Science and Technology (AIST)

As described in this paper, we analyzed the influence of the time necessary to begin coping behaviors on the damage caused by chemical terrorism. To calculate the damage of a chemical attack in a major rail station, our network model-based pedestrian simulator was applied with systems designed to predict hazards of indoor gas diffusion. Our network model is designed to conduct simulations much faster, taking less than few minutes for simulation with ten thousands of evacuators. Results of our analyses were used for the instruction of rail station managers in a tabletop exercise held by the Kitakyushu City Fire and Disaster Management Department.

An Evacuation Model for High Speed Trains

J.A. Capote, D. Alvear, O. Abreu, M. Lázaro and A. Cuesta, GIDAI Group, Fire Safety – Research and Technology. University of Cantabria (Spain)

In this paper we present a stochastic evacuation model specifically for high speed passenger trains. The proposed model is an object-oriented model in which passengers are represented using a cellular automata method and the train space by a fine network of 0.5 x 0.5m cells. The model is based on Monte Carlo methods in order to simulate the probability and effects of passengers' actions and decisions during the evacuation process. The datasets used as default by the model are taken from video recordings of evacuation drills and virtual experiments conducted at the University of Cantabria. However, the flexibility of the model allows the user to modify this data. The results of this model are then compared with other validated evacuation models. The proposed model has a simple user interface and the results are given in real-time. This model could be a useful tool for evacuation management during real emergencies. The advantages of using a stochastic approach for modelling passengers' behaviour in relation to a deterministic approach are discussed.

Comparison of a Grid-based and Continuous Space Pedestrian Model: Analysis of Normal Operations and Evacuation at a Train Station

Christian Castle and Nicholas Waterson, Mott MacDonald

Introduction

A clear evolution of pedestrian modelling has occurred, with a noticeable shift from aggregate to individual-level modelling. Castle and Longley (2008) broadly delineate the evolution of pedestrian evacuation modelling into five stages, from hand-based flow / hydraulic models to agent-based models that encapsulate human behaviour as well as movement. In tandem with the drive towards disaggregate based modelling of pedestrian dynamics, three distinct approaches to enclosure or geometry representation can be identified amongst current pedestrian modelling software. According to Castle (2007), these approaches can be defined as: 1) coarse network; 2) grid / cell-based and; 3) continuous space.

The manner in which a model represents an enclosure has a concerted affect on much of the simulation model. For example, coarse scale network models represent occupants en mass, with the aggregated homogenous population moving between discrete sections of a building (e.g. passageways, stairs and rooms), thus restricting the nature of these models to purely a consideration of movement. Applications that employ a grid or cell-based approach to enclosure representation have several advantages over coarse scale network applications. Firstly, the internal geometry of a structure can be represented

(e.g. furniture, columns, and ticket barriers). Secondly, every pedestrian can be represented as an individual, with different movement and behavioural characteristics allocated to each pedestrian if necessary. Alternatively, models that simulate the movement of pedestrians within a continuous space inherit all of the functionality of the grid / cell-based approach outlined above. However, the critical distinction between these approaches relates to the more precise representation of the internal layout, and thus an ability to more accurately simulate the movement and interaction of pedestrians within the enclosure.

A limited number of commercially developed and publicly available pedestrian modelling software have adopted the continuous space approach. One reason may be the computational expense required to simulate the movement of several thousand pedestrians with a rich set of behavioural and decision making characteristics. Indeed, reviews of pedestrian evacuation modelling software highlight that the predominant method of enclosure representation is the cell / grid-based approach, followed by the older generation of coarse network models, and subsequently continuous space models (refer to Gwynne et al., 1999; Galea et al., 2003; Olenick and Carpenter, 2003; RSSB, 2003; Santos and Aguirre, 2004; Kuligowski and Peacock, 2005; and Castle and Longley; 2008). With respect to the advantages and disadvantages to each modelling approach to enclosure representation, an interesting question hitherto not fully explored, is whether the simulation output is markedly different between these types of model? The purpose of this study is to explore this question.

Research Study

Cambridge rail station is a town within the UK that is a popular commuter route due to its proximity to London. In order to cope with the anticipated increase in future passenger demand, the station infrastruc-

ture must be upgraded in order to provide adequate capacity. Specifically, platforms will be added and the layout of the station will be altered to improve passenger circulation and increase capacity. Pedestrian simulation will be employed through a recently commissioned study to inform the design of the proposed station and evaluate different layout options.

With respect to the aim of this paper, evaluation of normal operational conditions and emergency egress at Cambridge station will be undertaken using two leading pedestrian modelling software. In particular, the pedestrian simulation software STEPS and Legion will be used to undertake the required analysis, which adopt grid-based and continuous space approach to enclosure representation (respectively).

In 2007 an extensive pedestrian survey was conducted at Cambridge station to determine the demand and movement of pedestrians within the station. In order to conduct the current pedestrian simulation analysis this data will be revised, which will be undertaking using automated video analysis of CCTV footage. The revised data will be used to calibrate both models of the station, and subsequently to validate the simulation (e.g. queuing and congestion at pivotal locations within the station).

As well as demonstrating the circulation of passengers within the station, output such as density / Level of Service and station usage over the peak period will be presented, in line with industry guidelines (Crossrail, 2008; and LUL, 2009). In addition queue length at gate-lines, journey time and total evacuation time will be explored to distinguish any difference between the model approaches, with respect to their output.

Summary

The purpose of this paper is to review a grid-based and continuous space approach to pedestrian modelling, in order to evaluate the significance of this approach to output generated. This paper will therefore serve to deliver insight of benefit to both practitioners of pedestrian modelling and the pedestrian modelling field in general.

Firstly, the paper will present the results of a revised real-world passenger demand survey conducted using automated video analysis. The methodology of this cutting edge approach to passenger surveying will be outlined, identifying best practice guidance, as well as demonstrating cost benefit of this approach in applicable circumstances.

Secondly, an impartial evaluation of output derived from two leading pedestrian modelling software will highlight some of the advantages and disadvantages of each approach to enclosure representation when analysing pedestrian circulation during normal conditions, and egress during an emergency.

Finally, guidance regarding the model building process of each software application will be presented, highlighting important considerations and some common pitfalls to model development.

While the building type and the software used to simulate pedestrian movement in this study are specific, the implications of the study are much more general in nature and aspects of wider application are considered throughout.

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General Model Development (2)

General Model Development (2)
Chaired by: Armin Seyfried

Quickest Cluster Flow Problems*
Horst W. Hamacher, Kathrin Leiner and Stefan Ruzika

Virtual Reality Simulation of Architectural Clues' Effects on Human Behavior and Decision Making in Fire Emergency Evacuation
Shaden Abu-Safieh

A Multi-Grid Model For Evacuation Coupling With The Effects of Fire Products
Zhiming Fang, Weiguo Song and Hao Wu

Quickest Cluster Flow Problems

H. W. Hamacher, K. Leiner, and S. Ruzika, Technical University of Kaiserslautern

Macroscopic models based on dynamic network flow theory are successfully applied to obtain lower bounds on real evacuation times [1]. The goal of our research is to tighten this lower bound and to make this macroscopic approach more realistic by taking into account clustering of evacuees - a sociological phenomenon observed in evacuation scenarios. A cluster of flow units in the network flow model represents families or cliques which tend not to move independently but as groups [2]. This fact is not covered by macroscopic approaches based on classical network flow theory. In this article, we take clustering into account and thus improve existing macroscopic network flow models. We focus on two different sizes of groups traversing the network, modeled as single flow units and cluster flow units the latter of which occupy d times as much capacity as single flow units. In this novel approach, we are given fixed amounts of single flow units and cluster flow units and minimize the time at which the last (single or cluster) unit reaches the target. We present an algorithm that gives a 2-approximation for general networks and is optimal for the subclass of series-parallel networks.

Virtual Reality Simulation of Architectural Clues' Effects on Human Behavior and Decision Making in Fire Emergency Evacuation

Sh. F. Abu-Safieh, Applied Science University

Disasters analyses have brought the interest in improving response to emergencies. In many cases there is a need to understand how people within a built environment react in a fire building emergency. Architectural clues play a significant part in the decision making and time taken to evacuate due to an emergency. In this study, virtual reality simulated experiments have been constructed to study the human ability to stay oriented while moving through spaces, evaluating alternatives and making decisions. Two variable models were constructed and implemented in a simulated built environment, in which 100 subjects were tested as in evacuation experiment. Data analysis shows how these variables affect human behavior on each critical decision points. Results showed that some architectural clues such as: windows and colors are important factors in the process of determining and following a route in fire emergency evacuation.

A Multi-Grid Model For Evacuation Coupling With The Effects of Fire Products

Zhi-Ming Fang, Wei-Guo Song, Hao Wu, SKLFS, University of Science and Technology of China.

The effects of fire products on pedestrians are introduced into a multi-grid evacuation model, in which the space is discretized into smaller grids with the size of 0.1m×0.1m and each pedestrian occupies 5×5 grid sites. The effects of fire products on pedestrians consist of two parts: the desired movement direction and the step frequency. The data of fire products obtained from the simulation results of a well-founded computational fluid dynamic (CFD) program, the Fire Dynamics Simulator (FDS) developed by the National Institute of Standards and Technology (NIST). With the multi-grid model, we investigated the walk routes of pedestrians in fires, and the evacuation time in scenarios with different fire intensities, pre-movement times or door widths.

Session: Model Calibration/Validation (1)

Model Calibration/Validation (1)
Chaired by: Steve Gwynne

Towards Automatic and Robust Adjustment of Human Behavioral Parameters in a Pedestrian Stream Model to Measured Data.
Maria Davidich and Gerta Koester

Comparing Pedestrian Movement Simulation Models For a Crossing Area Based on Real World Data
Dietmar Bauer

Towards a Calibration of the Floor Field Cellular Automaton
Andreas Schadschneider, Christian Eilhardt, Stefan Nowak and Robinson Will

To See Behind the Curtain – A Methodical Approach to Identify Calculation Methods of Closed-Source Evacuation Software Tools
Christian Rogsch and Wolfram Klingsch

Towards Automatic and Robust Adjustment of Human Behavioral Parameters in a Pedestrian Stream Model to Measured Data

M. Davidich and G. Koester , Siemens AG

People die or get injured at mass events when the crowd gets out of control. Urbanization and the increasing popularity of mass events, from soccer games to religious celebrations, enforce this trend. Thus, there is a strong need to find a better means to control crowd behavior. Here, simulation of pedestrian streams can be very helpful: Simulations allow to run through a number of scenarios in a critical situation and thereby to investigate adequate measures to improve security. In order to make realistic, reliable predictions, a model must be able to reproduce quantitatively the data, known from experiments. Therefore, automatic and fast calibration methods are needed that can easily adapt model parameters to different scenarios. Also, the model must be robust: Small changes in the crucial input parameters must not lead to large changes in the simulation outcome. In this paper we represent two methods to automize the calibration of pedestrian simulations. We then introduce a concept of robustness to compare the two methods. In particular, we propose a quantitative estimation of parameter quality and a method of parameter selection based on robustness criteria.

Comparing Pedestrian Movement Simulation Models For a Crossing Area Based on Real World Data

D. Bauer, Austrian Institute of Technology

In this paper two different pedestrian movement simulation models (a model of the social force type and a queuing network model) are compared with respect to their capability to predict individual walking times in a crossing area. Both models are calibrated using a trajectory data set and their relative performance on the estimation data set as well as on a separate validation data set is discussed. The social force type model is found to better predict the walking times as well as space usage in both in- and out-of sample comparison.

Towards a Calibration of the Floor Field Cellular Automaton

Andreas Schadschneider, Christian Eilhardt, Stefan Nowak and Robinson Will, Institut für Theoretische Physik, Universität zu Köln

We discuss several aspects related to the validation and calibration of cellular automata based models of pedestrian dynamics. Empirical fundamental diagrams obtained in large-scale experiments are compared with simulations of the floor field model. Although this kind of macroscopic calibration gives insights into the relevant interactions that govern the collective behaviour of pedestrians, microscopic validation based on the trajectories is expected to be more reliable. As a simple scenario we consider trajectories of the motion of individual pedestrians around corners. It is found that besides interactions with walls inertia effects play an important role for the correct reproduction of the empirical trajectories.

To See Behind the Curtain – A Methodical Approach to Identify Calculation Methods of Closed-Source Evacuation Software Tools

Christian Rogsch and Wolfram Klingsch, University of Wuppertal, Institute for Building Material Technology and Fire Safety Science

Commercial software-tools for evacuation calculation are mostly closed-source (also called “proprietary”) software-tools. Contrary to open-source software tools users of these closed-source software-tools have to trust the technical manual of the software to understand how the software works. For users it is important to know how the model they use works, because without this knowledge results calculated by the software-tool can be interpreted in a wrong way. We will present a methodology how to identify basics of evacuation modelling and how to interpret and understand calculated results in a better way. This methodology should give users a “better feeling” in a very short time for the model they use for evacuation analysis and calculation.

Session: Modeling Methods (Spatial)

Modeling Methods (Spatial)
Chaired by: Pete Thompson

Implementing a Hybrid Space Discretisation Within an Agent Based Evacuation Model
Nitish Chooramun, Peter Lawrence and Edwin Galea

Bidirectional Coupling of Macroscopic and Microscopic Approaches For Pedestrian Behavior Prediction
*Angelika Kneidl, Markus Thiemann, André Borrmann, Stefan Ruzika, Horst W. Hamacher, Gerta Köster, Ernst Rank**

Emergency Evacuation Modeling: A Novel Approach to Layout Designs and Evacuation Procedures
Rani Kady and Andreas Tolk

The Use of Fine – Coarse Network Model For Simulating Building Evacuation With Information System
Marcin Cisek and Michal Kapalka

Implementing a Hybrid Space Discretisation Within An Agent Based Evacuation Model

N. Chooramun, P.J. Lawrence and E.R.Galea, Fire Safety Engineering Group, University of Greenwich,

Egress models typically use one of three methods to represent the physical space in which the agents move, namely: coarse network, fine network or continuous. In this work, we present a novel approach to represent space, which we call the 'Hybrid Spatial Discretisation' (HSD), in which all three spatial representations can be utilised to represent the physical space of the geometry within a single integrated software tool. The aim of the HSD approach is to encompass the benefits of the three spatial representation methods and maximise computational efficiency while providing an optimal environment to represent the movement and interaction of agents.

Bidirectional Coupling of Macroscopic and Microscopic Approaches for Pedestrian Behavior Prediction

Angelika Kneidl, Markus Thiemann, André Borrmann, Stefan Ruzika, Horst W. Hamacher, Gerta Köster, Ernst Rank, Technische Universität München, Technische Universität Kaiserslautern and Siemens AG

We combine a macroscopic and a microscopic model of pedestrian dynamics with a bidirectional coupling technique to obtain realistic predictions for evacuation times. While the macroscopic model is derived from dynamic network flow theory, the microscopic model is based on a cellular automaton. Output from each model is fed into the other, thus establishing a control cycle. As a result, the gap between the evacuation times computed by both models is narrowed down: the microscopic approach benefits from route optimization resulting in lower evacuation times. The network flow approach is enriched by including data of microscopic pedestrian behavior, thus reducing the underestimation of evacuation times.

Emergency Evacuation Modeling: A Novel Approach to Layout Designs and Evacuation Procedures

R. A. Kady and A. Tolk, Department of Engineering Management and Systems Engineering, Old Dominion University

The development of evacuation models in the last three decades has mainly contributed to the assessment of occupant safety and evacuation procedures in a variety of building designs, under a range of environmental conditions. The effectiveness of such evaluation relies mainly on the models ability to reflect the detailed interactions between the occupant, building design, and environment. The purpose of this study is to present emergency evacuation modeling as a novel approach to layout designs and evacuation procedures. The approach is based on the development of a novel evacuation model that adjusts its outputs to evaluate a range of layout designs. The proposed evacuation model relies on the application of evolutionary computation techniques to assess the means of egress by evolving the location and number of exits needed to ensure occupants safety. The performance of the algorithms varies by occupant behavior. The study suggests that the algorithms have the potential to be implemented in more complex design problems. The study further suggests the need to validate the configurations found by the algorithms by conducting actual evacuation drills.

The Use of Fine – Coarse Network Model For Simulating Building Evacuation With Information System

M. Cisek and M. Kapalka, The Main School of Fire Service SGSP and Military University of Technology WAT

In this article, the optimization problem of evacuation of a building with many escape routes with consideration of dynamic changes in people – building- threat interactions is described. The model of system conveying information of the best way of evacuation with taking into account the people who will not adapt to the recommendations is proposed. On the base of chosen strategy of evacuation in every place of the building where direction of evacuation can be changed, the proposed system will give full information about the evacuation possibilities and recommends one of the routs. In the agent model, the individual characteristics affecting the decision-making process are been proposed. Self developed microscopic model of human behavior was used to simulate the evacuation problems. The representation of model environment uses a combination of two approaches: coarse network model and fine network model simultaneously. During the simulation, the main factor influencing the path of movement of individuals is the information supplied by the shared information system of the best way. In addition to a certain probability can decide to change the route of the evacuation.

Model Calibration/Validation (2)

Model Calibration/Validation (2)
Chaired by: Christian Rogsch

Analyzing Stop-and-Go Waves by Experiment and Modeling

Portz and A. Seyfried, Jülich Supercomputing Centre and Forschungszentrum Jülich GmbH

The main topic of this paper is the analysis and modeling of stop-and-go waves, observable in experiments of single lane movement with pedestrians. The velocity density relation using measurements on a 'microscopic' scale shows the coexistence of two phases at one density. These data are used to calibrate and verify a spatially continuous model. Several criteria are chosen that a model has to satisfy: firstly we investigated the fundamental diagram (velocity versus density) using different measurement methods. Furthermore the trajectories are compared to the occurrence of stop-and-go waves qualitatively. Finally we checked the distribution of the velocities at fixed density against the experimental one. The adaptive velocity model introduced satisfies these criteria well.

Experimental Study of Crowd Flow Passing through Simple-shaped Room and Validation for an Evacuation Simulator

Tomonori Sano[1], Yoshiyuki Yoshida[2], Naohiro Takeichi[2], Takeshi Kimura[3], and Yoshikazu Minegishi[2], [1]Faculty of Human Sciences, Waseda University, [2]Takenaka Corporation, and [3]A & A Co., Ltd.

This paper describes the characteristics of crowd flow passing through simple-shaped rooms and to validate an evacuation simulation model called "SimTread". It presents experiments on crowd flow with 43 subjects and intends to quantify the aspects of crowd flow in simple rooms. Recently, for estimating evacuation of buildings on fire, several computer simulation models have been developed and applied. However, human evacuation data-sets for validating simulation are scarce. The results of this study show that pedestrian flow rate at the opening changes depending on the density of the space connected. Flow rate rises if the opening is connected to larger space, which is less dense and, in result, increases speed of pedestrians. For validating an evacuation simulator, evacuation data from actual building fires are too complex for proving the equivalence. Therefore, we carried out the experiments of crowed flow passing through simple-shaped rooms, and compared experimental data with our simulation results. There was a good agreement between the result of experiments and simulations. The differences were less than 10%.

Calculating and Verifying the Staircase-length for Evacuation Analysis

Hyun-seung, Hwang. Jun-ho, Choi. Won-hwa, Hong., School of Architecture, Kyungpook National University.

Recently, evacuation analysis, which is one of the performance-based evacuation design methods, has been widely used to estimate the egress capacity of buildings and analyze evacuees' characteristics. But almost all the models do not consider accurate evacuation scenarios because of the limitation of simulations, especially when setting up the staircase-length in building geometry mode. Therefore, this study selected a subject of a high-rise building with 351 invited participants, and conducted an experiment to investigate the evacuation from the 30th floor to the ground level and then classified overall 5,265 movement cases to calculate the participants' evacuation route. After the trial experiment, the paper calculated the precise average distance of participants' evacuation route in staircases considering each zone's length and dimension and derived the numerical equations for inputting the parameter of staircase-length in evacuation models. and the verifications were also conducted by comparing simulations with the results of the experiment.

Modeling Methods (General)

Modeling Methods (General)
Chaired by: Ai Sekizawa

Simulation of Pedestrian Flow outside a Single-exit Room in Mean-Field Approximation Model

Jun Zhang[1,2] and Weiguo Song[2], [1]University of Wuppertal, Institute for Building Material Technology and Fire Safety Science and [2]University of Science and Technology of China

In this study, a framework model, based on lattice gas model and Mean-Field Approximation model, is proposed to analyze pedestrian evacuation uncertainty. The model is focused on the probability that each grid is occupied by a pedestrian, but not the specific pedestrians. By calculating the evolution of occupancy probabilities, more information about the simulation uncertainty can be gotten. The model is presented in terms of a series of nonlinear equations and complete probability formula. In each time step, the probabilities that pedestrians exist on each site, as well as the transition probabilities to the neighboring sites, are calculated and updated using random sequential update rule. The pedestrian flow going outside a single-exit room is investigated numerically. The cumulative distribution and probability density distribution of the total evacuation time can be obtained by a single simulation using the model. In this case, the uncertainty and reliability of the simulation results can be easily analyzed and improve the calculation efficiency. In addition, the time dependent of mean flow rate and the effect of the width of exit on the total evacuation time are studied. The framework model can be extended using other Cellular Automaton model with different rules to analyze their uncertainty.

A Sandwich Approach for Evacuation Time Bounds

H.W. Hamacher, S. Heller, W. Klein, G. Köster and S. Ruzika, TU Kaiserslautern and Siemens AG

In this article, we propose a novel modeling approach – the sandwich approach – to deal with evacuation time bounds (ETB) - in which lower and up-per bounds for the evacuation time are calculated. A provable lower bound is achieved by computing a quickest flow, using a dynamic network flow model, an upper bound is obtained via simulation using a cellular automaton model. Coherence between the macroscopic network flow and the microscopic simulation model will be discussed. In order to validate our theoretical results, we report on our practical experiences with the Betzenberg, the region containing the Fritz-Walter soccer stadium in Kaiserslautern, Germany.

A Knowledge-Based Approach to Crowd Classification

S. Bandini, L. Manenti, S. Manzoni and F. Sartori, Department of Informatics, System and Communications, University of Milano – Bicocca

This paper illustrates a formal tool for knowledge representation and management in the crowding area, in order to improve on the sharing of knowledge, data and information produced by different models and simulation tools. The presented approach exploits knowledge-based methods for acquisition and representation phases.

After a short discussion about crowd research area, we will present the methodology we have used to develop the tool. It is composed by an ontology and a set of fuzzy rules, which provided crowd classification according to a sociological theory previously formalized.

At last, in order to show how using the tool, a case study on a particular crowd scenario is proposed.

Towards Realistic Modeling of Crowd Compressibility

Jarosław Wąs, Wojciech Myśliwiec, Robert Lubaś, Institute of Automatics, AGH University of Science and Technology

The article presents a new approach to crowd compressibility modeling in pedestrian evacuation. The model is based on Social Distances Model and implements a compressibility coefficient. The main purpose was to study specific flow of pedestrians through bottlenecks. Real data from two experiments were used to validate received results. Differences in compressibility parameters significantly influence pedestrian behavior and simulation scenarios. Higher values of compressibility coefficient lead to increased densities and flow of pedestrian stream.

Session: Vertical Egress

Vertical Egress, Chaired by: Peter Johnson, Arup

Addressing the Needs of People using Elevators for Emergency Evacuation
Richard Bukowski

Stairs or Lifts? – A study of Human Factors associated with Lift/Elevator usage during Evacuations using an online Survey
Michael Kinsey, Edwin Galea and Peter Lawrence

Elevator Evacuation Algorithms
Marja-Liisa Siikonen and Janne S. Sorsa

Experiments for the Feasibility Study of the Evacuation by Moving Escalator in Public Space
Emi Okamoto, Yuji Hasemi, Shuji Moriyama and Naoko Okada

Addressing the Needs of People using Elevators for Emergency Evacuation

Richard W. Bukowski, P.E., FSFPE, Rolf Jensen & Associates

US model codes and building regulations are recognizing the provision of protected elevators for occupant self-evacuation after more than two decades of training people that elevators are unsafe in fires. This reversal will require that people can readily identify those elevators that are safe to use and be provided with information and reassurances during use that the system is functioning safely.

Lengthy discussions on the interactions between the systems and users have resulted in requirements for visual, audible, and voice messaging systems and operational protocols designed to provide reliable, real-time information needed by users to make informed decisions. The discussions have further identified the need for public education to provide for effective use by infrequent visitors to buildings equipped with these systems.

The paper will discuss the approaches being developed to address these needs by a consortium of public and private organizations including the American Society of Mechanical Engineers (ASME), National Institute of Standards and Technology (NIST), National Elevator Industry Inc. (NEII), disability advocacy groups, and the fire alarm and model building code developers. There is an expectation that since a building's elevators are used daily by the occupants, by keeping the system used in emergencies as close as possible to normal use, the provision of additional information on status and safety will represent sufficient reassurance to users.

One of the outstanding issues identified in the discussions is the need for testing and verification that the approaches will be effective. Due to the difficulties inherent in human testing, there is a need for the inclusion of these features into observational research being conducted through required evacuation drills. Since elevator use is not prohibited now for non-fire emergency egress, this may provide the opportunity to test public response to the approaches being contemplated. The paper will suggest ideas for such research being included in planned studies and as a part of building commissioning.

Stairs or Lifts? - A Study of Human Factors associated with Lift/Elevator usage during Evacuations using an online Survey

M.J Kinsey, E.R Galea, and P.J Lawrence, Fire Safety Engineering Group (FSEG), University of Greenwich

This paper presents an overview of human factors data collected via an online survey related to the use of lifts (elevators) and stairs during both circulation and evacuation scenarios. Survey participants were presented with a series of hypothetical situations and asked how they would behave. The survey was split into two broad sections, the first dealing with normal circulation usage of lifts/stairs and the second dealing with evacuation usage of lifts/stairs. Detailed demographic information about each participant was also collected. In total some 468 people from 23 countries completed the survey. An overview of the survey and initial results are presented in this paper.

Elevator Evacuation Algorithms

M-L. Siikonen and J. S. Sorsa, KONE Corporation

In emergency situations, the practice has been to return elevators to the exit discharge level, and then shut down. After that, the elevators are not available for the building occupants until the emergency is over. In this paper, we study the use of the elevators in an emergency evacuation. We first introduce the theoretical egress time and the handling capacity calculation for an elevator group, which is based on floor-by-floor evacuation. We also describe a specialized elevator evacuation algorithm, which automatically, with or without landing call information, dispatches elevators to the occupied floors and shuttles passengers to the rescue level. The algorithm serves floors in a priority order and detects floor occupancy automatically. We compare this algorithm to a normal algorithm and to two staircases in evacuation. For that purpose, we run simulations of test buildings with realistic transport arrangements and obtain performance measures such as crowding levels of the lobbies, passenger service times and total evacuation time. On this basis, we propose the best algorithm for different types of emergencies.

Experiments for the Feasibility Study of the Evacuation by Moving Escalator in Public Space

Emi OKAMOTO, Yuji HASEMI, Shuji MORIYAMA and Naoko OKADA, Department of Architecture, Waseda University

This paper reports experiments on the reaction of pedestrians to the sudden stop and restarting of an escalator to explore the applicability of escalators moving toward safer side. Deceleration rate at the stop and acceleration at the restarting were controlled so that optimum operation to keep the safety of pedestrians were sought. 32 experiments were conducted on each of 10 subjects(6 females and 4 males) by changing the moving/still mode of the escalator, moving direction of escalator(upward/downward), deceleration and acceleration rates, walking/still standing modes of the subjects, and burden conditions. The experiments indicate restarting generally safer than stopping, downward operation generally safer than upward one, and significance of the influence of the burden condition to the safety of pedestrians at emergency stopping and restarting. The difference whether the pedestrian walks or stands still did not cause significant difference in the pedestrians' safety. The experiments also indicate significant effectiveness of the reduction of the deceleration rate at emergency stopping from the current 0.61 m/s^2 to 0.43 m/s^2 and the acceleration rate at emergency restarting from the current 0.17m/s^2 to 0.10 m/s^2 for the improvement of the pedestrians' safety.

Real Events

Real Events
Chaired by: Winnie Daamen

Assessing Crowd Dynamics and Spectator Safety in Seated Areas at a Football Stadium
Zachary Au, Jenny Gilroy, and R.A. Haslam

Stay Or Go? Human Behavior In Major Evacuations
Peter Johnson, Claire Johnson and Carolyn Sutherland

Analysis of Occupant Behavior during a High-rise Office Building Fire
Erica Kuligowski and Bryan Hoskins

The Lame Horse Night-Club Fire: Disaster Timing*
I.P. Belosokhov, D.A. Samoshin, B.B. Serkov, V.V. Kholshevnikov

Assessing Crowd Dynamics and Spectator Safety in Seated Area at a Football Stadium

S.Y.Z. Au, J. Gilroy and R.A. Haslam, Human Interactions Limited

This paper presents a study at the Manchester United Football Stadium at Old Trafford, UK. The purpose of the study was to assess the safety risks associated with spectators standing in an all-seated stadium. Information gathering was a key part of the study; this paper looks at the information gathering exercises undertaken and how they contributed to the risk assessment. It also presents some of the key study findings. It may not be immediately apparent that standing in a stadium that is not overcrowded could be an issue. But there are in fact a variety of movements and behavioral factors involved when people stand. It is these movements and behaviors and their interactions with the physical environment that was our focus of investigation. Overall, the study has found that the risk of standing varies depending on the situation and the physical design of the seated area. There are a number of risk factors involved; we believe that many of them can be controlled through stadium design and crowd management.

Stay Or Go? Human Behavior In Major Evacuations

P.F.Johnson[1], C.E.Johnson[2] and C.Sutherland[3], [1]Arup, [2]Latrobe University, School of Psychological Sciences, and [3]Monash University, Department of Business Law and Taxation

Human behaviour in building evacuation and use of elevators has been studied more extensively in recent years. There is also a move to explore concepts of "protect-in-place", thus avoiding evacuation in some circumstances. This raises the matter of decision making as to whether to "stay or go". In the fields of natural hazards, such as bushfires and floods, this decision to "stay or go" becomes equally important for safety. A comparison of literature sources on human behaviour and decision making in buildings with recent research on bushfires and floods highlights some common factors critical to decision making as to evacuation or not. These factors include emergency preparedness, situation awareness and trusted information systems. This paper suggests that greater understanding of group behaviour and socio-cultural differences is required if more effective emergency management is to be achieved.

Analysis of Occupant Behavior during a High-rise Office Building Fire

E. D. Kuligowski and B. Hoskins, National Institute of Standards and Technology

Survey responses from occupants involved in a 32-story high-rise building evacuation during an actual fire were collected and analyzed to study the pre-evacuation period. Multiple regression models were used to test whether specific occupant, building, and environmental factors predicted pre-evacuation times. The type of information and the specific actions taken by respondents were found to directly influence pre-evacuation times, and the amount of pre-evacuation time was quantified for each influential factor.

Session: Regulation/Engineering Guidance

Regulation/Engineering Guidance
Chaired by: Jason Averill

Accessibility and Evacuation Planning – Similarities and Differences
Judith Bendel and Hubert Klüpfel

Micro-Simulation Modeling of Persons with Reduced Mobility: Is the London Framework Applicable in North America and Does it Affect Modeling Output?
Daniel Fisher and Andrew Jenkins

Prospects for the Design of Cognitive Systems that Manage the Movement of Large Crowds
Norman Groner, Elise Miller-Hooks and Lei Feng

Risk Management at Major Events - Study of Behavioural Aspects and Implementation into the ASERI Microscopic Evacuation Model
Rainer Könnecke and Volker Schneider

Accessibility and Evacuation Planning – Similarities and Differences

Judith Bendel and Hubert Klüpfel, Access Unlimited and TraffGo HT GmbH

Introduction

Twenty–twenty four percent (20-24%) of the world population are people with disabilities (U.S. Census Bureau, 2005; Australian Bureau of Statistics, 2004; EU commission, 2003). In numbers it means for example 42 million people of the European Community, 45 million Americans and 4million Australians are people with disabilities. This population has special access needs for performing activities of daily living. This is especially true and important in case of an emergency such as evacuation. One should not assume that individuals with obvious physical disabilities are the only ones who will have difficulties evacuating. Individuals with a range of medical conditions — hidden disabilities including asthma or heart conditions — or any occupant who is recuperating from an injury or surgery might have difficulty using steps during an evacuation.

In view of the 2010 "Europe Accessible for All" plan of the European Commission, carried out in the broader context of sustainability of the built environment, with a particular focus on various aspects of designing buildings and open public spaces for all, the use of the facilities as well as its evacuation are an integral aspect of the design. An evacuation plan MUST cover people with disabilities; any evacuation training must include training for the evacuation of people with disabilities. Despite of its importance, most current evacuation simulation models do not take into consideration many aspects of evacuation specific to people with disabilities and the elderly and they do not adequately address individuals with disabilities in their simulated populations...

The “Time” Factor in Accessibility and Evacuation

Evacuation is not the same as accessibility, as the 'time'-factor plays a more restrictive role in the case of evacuation. Nevertheless, evacuation and accessibility have much in common and they complement each other. For example, the spatial configuration and occupancy of rooms, obstacles, route marking as well as other factors related to various types of disabilities need to be explicitly taken into account in both fields.

Anthropometrics, Ergonomics, and Pedestrian Movement

The physical, sensory and mental fitness of the populations in western society changes, as well as the age distribution. Age, as well as other factors like obesity, medical conditions etc. have an impact on the walking speed. These factors affect accessibility needs as well as evacuation performance. Therefore, the special needs as well as the predicted demographic changes have to be taken into account for pedestrian planning and design.

Micro-Simulation Modeling of Persons with Reduced Mobility: Is the London Framework Applicable in North America and Does It Affect Modeling Output

Fisher D.A and Jenkins A, Arup Consulting Inc

Transit authorities globally are developing their networks to make them more accessible for Persons with Reduced Mobility (PRM's) whilst demographic and lifestyle trends suggest that the proportion of PRM's within the population who are likely to make use of these newly accessible networks will increase over time. In the UK, London Underground has developed a modeling framework that incorporates PRM movement into pedestrian micro-simulation models. Network Rail, the UK mainline station operator has also been undertaking PRM surveys to determine the characteristics of PRM demand at mainline stations and this data validates the approach adopted by LUL which requires a location specific understanding of PRM populations, incorporates spatial and temporal variation, and is coupled to location specific characteristics (for example, Network Rail long distance passengers are less familiar with their station environment than commuters and require more information, signage and management. They are more likely to travel in groups and be encumbered).

Anecdotal evidence from studies completed in London suggests modeling output is sensitive to the volume of PRM's modeled. To date, no detailed reviews have been undertaken to assess this sensitivity. This paper reviews the PRM modeling methodology used in London and assesses its applicability in the America's and elsewhere. The relationship between maximum flow rates and the average speed and footprint of entities is tested through the use of Legion micro-simulation models and described through the application of multi-variable linear regression to the output. Impacts of modeling PRM's are described and implications for Space Planning Performance Metrics and design recommendations are reviewed.

Prospects for the Design of Cognitive Systems that Manage the Movement of Large Crowds

N. E. Groner[1], E. Miller-Hooks[2], and L. Feng[2], [1] Department of Protection Management, John Jay College, City University of New York, [2] Department of Civil and Environmental Engineering, University of Maryland,

Environmental uncertainties and the complexities of human behavior create challenges in the design of adaptive crowd management systems. The authors suggest a computer-assisted management system based on principles of cognitive systems engineering, including distributed decision-making agents with variable goals, and feedback loops that facilitate adaptation. A computer-based tactical crowd advisor uses a behavioral model to suggest actions to the crowd manager based on the behavioral model's predictions of crowd movement. The crowd manager instructs security personnel and pedestrians, and observes the results, thus completing a feedback loop. An agent-based simulation is used to generate behavioral input so that the expected effects of physical and procedural features of alternative proposed systems. The basic principles of the cognitive systems approach adopted herein are illustrated using examples from an investigatory report of the Presidential Inauguration in Washington D.C. in January of 2009.

Risk Management At Major Events - Study of Behavioral Aspects and Implementation Into The ASERI Microscopic Evacuation Model

R. Könnecke and V. Schneider, IST GmbH

EVA is the acronym for an interdisciplinary research project addressing risk management of major events. The focus here is on the behavioral aspects of crowd movement at annual fairs, festivals, large parades or sport events. As a first step, video recordings at accentuated places are taken and analyzed. The respective findings are next included into the microscopic evacuation model ASERI developed by IST GmbH. The so expanded model is now in the process of validation against available empirical data and will be used to investigate crowd movement in normal and perturbed cases including emergency scenarios. Emphasis is put on social interactions and collective effects like group formation and persistence and the interaction of crowd flow with technical provisions and organizational measures. Ultimate goal of the EVA project is the development of a guideline on the evacuation of large scale event spaces in cooperation with German municipal fire brigades.